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REMOTE SENSING PROGRAM

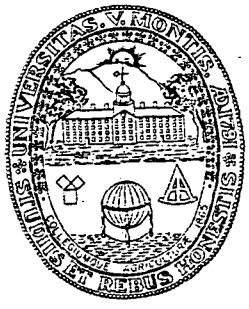
NASA GRANT NSG-7453

ANNUAL REPORT

June 1, 1978 - May 31, 1980

supported by

National Aeronautics and Space Administration



UNIVERSITY OF VERMONT

SCHOOL OF NATURAL RESOURCES

BURLINGTON, VERMONT

ANNUAL REPORT AND SUMMARY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Grant NSG-7453

by

Remote Sensing Program
School of Natural Resources
University of Vermont
Burlington, Vermont 05405

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Report for Period

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
PROGRAM HIGHLIGHTS	1
PROGRAM IMPACT	2
GENERAL EDUCATION AND TECHNOLOGY TRANSFER	4
SYSTEM DEVELOPMENT FOR DATA HANDLING AND ANALYSIS	11
THE VERMONT LAND COVER CLASSIFICATION	17
A REMOTE SENSING APPROACH TO LAND USE CHANGE IN VERMONT	21
LAND COVER/USE CLASSIFICATION FOR PLANNING	28
REMOTE SENSING INVENTORY AND INFORMATION SYSTEM	31
LAND COVER/USE CHANGE FOR WATERSHED MONITORING	36
FOREST INSECT DEFOLIATION DETECTION	40
LAKE AND POND WATERSHED COVER MAPPING	43
LANDSAT LAND COVER CLASSIFICATION FOR 19 RIVER WATERSHEDS IN VERMONT	45
CONIFEROUS SPECIES DIFFERENTIATION	49
WATER QUALITY MONITORING	52
WATER USE CONFLICT STUDY	55
WATER BODY INVENTORY	57
APPENDIX TABLES (PROJECTS)	59
APPENDIX (COURSES)	62

INTRODUCTION

In June, 1978, The School of Natural Resources at the University of Vermont was awarded NASA Grant NSG-7453 for a three year project entitled "The Development of a Remote Sensing Applications Program for Vermont". The purpose of this program is to encourage investigation and technology transfer for practical applications of remote sensing technology to solve earth resource problems. This project was renewed at first year level funding in June 1979 and again in June 1980.

The primary objectives of this program as originally stated remain unchanged and are as follows:

1. To test and evaluate the applicability of remote sensing technology to the solution of specific problems faced by resource managers and decision makers at the local, town, county and state levels.

2. To identify mechanisms and implement procedures for the transfer of applicable technology to appropriate user groups and for user groups to transmit needs to individuals competent in remote sensing technology.

3. To enhance the comprehensive education and research programs of the University of Vermont by presence of resident expertise in remote sensing technology and the development and acquisition of this technology.

The Grant has provided most of the Program's funding during the first two years of its existence. Our management philosophy has been to conduct activities within the framework of the stated objectives.

PROGRAM HIGHLIGHTS

During the initial year, activities were undertaken in areas related to meeting all three of the objectives. Particular emphasis was placed on activities concerned with the development of resident technical

expertise and resources. At the same time, activities to acquaint potential users with the benefits of remote sensing technology were conducted. During this same year several applications projects were initiated.

During the second year greater emphasis was directed toward the undertaking of applications projects that would promote and expand the use of remote sensing as an efficient means of helping solve earth resource problems. Most of these have examined methods of detecting or monitoring a problem or to provide a data base for more comprehensive analysis.

Major accomplishments during the first two years of Grant funding include the following:

1. Acquisition, installation and operation of the ORSER digital processing system on the UVM IBM 3031 computer.

2. Acquisition and operation of printing and CRT computer terminals for remote access to computer facilities for analysis of remotely sensed digital data.

3. Acquisition and operation of optical interpretation and image transfer devices for use with all types of aerial photography.

4. Development of audio-visual and other training materials for use in presentations, workshops and short courses to enhance technology transfer.

5. In cooperation with federal, state and local agencies develop some eleven demonstration projects both large and small to show the feasibility of using remote sensing technology as a means of acquiring various kinds of useful environmental information.

PROGRAM IMPACT

As a result of this program many outside organizations, federal, state, local as well as private have begun to use remote sensing technology in their day to day activities. Many organizations who might not have done so otherwise, are active users today. The program has

become a major remote sensing technology resource in Vermont and northern New England. During the second year of the program more than fifty inquiries were received in the form of telephone calls, letters and personal visits. It is safe to say that little, if any, of this would have occured without the program funding from NASA. Although large strides have been made toward greater acceptance and use of modern remote sensing technology, there is still insufficient knowledge among potential users as to what is available and how it can be applied.

The following pages provide descriptive information on Grant funded projects during the first two years of the program. Following these are tabular summaries of specific project activities, and an additional table showing remote sensing educational activities including courses and enrollments. Many of these have benefitted directly through the availability of program resources and facilities. Six graduate students have been directly involved in project work and two of these have been entirely supported by grant funds.

GENERAL EDUCATION AND TECHNOLOGY TRANSFER

Background and Objectives

Before the initiation of the Remote Sensing Applications Program at the University of Vermont in 1978, the use of modern remote sensing technology within Vermont was limited to the use of conventional aerial photography for planning, highway engineering and cover type mapping. Systems and equipment for the use of this imagery were limited to facilities at the University and the State Highway Department. Before any new technology can be adopted, potential users must be aware of its existence, then convinced of its usefulness. Beyond this they must be shown how it can solve their specific resource-related problems. Only when these conditions are met can demonstration projects be initiated.

With these concepts and their orderly sequence in mind, a project, specifically oriented to general remote sensing education and technology transfer, was developed as a continuing activity.

Methodology

Awareness of remote sensing technology has been, in part, achieved through newspaper and television, and by word of mouth. Information concerning the establishment of the program and of the receipt of the grant from NASA has been disseminated to the general public and copies of press releases sent to potential interested organizations and individuals.

After developing and acquiring suitable audio-visual materials, a number of presentations have been given to general and technical interest groups (Table 1). One of the most significant of these was a presentation in February 1979 to a joint session of the Vermont House and Senate Committees on Appropriations and Natural Resources.

Table 1. Workshops and Presentations, Remote Sensing Applications Program, School of Natural Resources, University of Vermont.

TYPE	DATE/S	GROUP	ATTENDANCE
Short Course (ORSER)	January 8-12, 1979	UVM Faculty & State Agencies in cooperation with ERRSAC	12
Presentation	February 8, 1979	Vermont House and Senate Appropriations and Natural Resource Committee, Montpelier, VT	30
Presentation	April 6, 1979	New York State Agency Personnel, Oneata, NY	50
Presentation	September 28, 1979	Remote Sensing Group of Northern New England	30
Presentation	October 4, 1979	ERRSAC Regional Conference, Easton, MD	100
Presentation	December 7, 1979	New Hampshire State Agencies, Concord, NH	60
Tour/Presentation	February 14, 1980	South Burlington High School Science Class	20
Workshop	April 1, 1980	Vermont Department of Forests and Parks	16
Presentation	May 13, 1980	Burlington Lions Club	40
Workshop	May 21, 1980	Vermont Department of Forests & Parks, Rutland District	12
Workshop	May 22, 1980	Vermont Department of Forests & Parks, Springfield Office	10
Workshop	May 28, 1980	Vermont Department of Forests & Parks, Essex District	11
Tour/Presentation	June 3, 1980	Agency Heads, Vermont Agency of Environmental Conservation	12
Tour/Presentation	June 11, 1980	FRAC, Vermont Forest Resources Advisory Committee	8
Tour/Presentation	July 25, 1980	U.S.D.A., Northeast Regional Research Technical Committee	18
Workshop	August 18, 1980	Vermont Fish & Game Department, Regional Biologists	10

As a result of these awareness activities, the Agency of Environmental Conservation requested that we conduct a series of one day workshops on "modern remote sensing technology" for selected groups of their professional personnel. After preparing a syllabus in cooperation with agency personnel and developing appropriate training materials, five such sessions were conducted (Figure 1).

The syllabus and materials for these workshops is site specific and encompasses the area covered by the USGS 7½ minute Bomoseen quadrangle. This area includes a variety of cover types and land uses and has been subject to rapid change over the past twenty years. It affords an excellent opportunity to demonstrate a variety of techniques and equipment. The area has been covered by a range of image products through several sensors over a wide range of time. Image materials in the instructional package include:

1:20,000 Black and white panchromatic photos
1:80,000 Color infrared photos
Landsat FCC print path 15, row 29 (#30170-15011)
Landsat band 4 print path 15, row 29 (#30170-15011)
Landsat band 5 print path 15, row 29 (#30170-15011)
Landsat band 6 print path 15, row 29 (#30170-15011)
Landsat band 7 print path 15, row 29 (#30170-15011)
Landsat FCC print path 15, row 29 (#05195-14415) enhanced

A land cover overlay for the quadrangle was prepared from the color infrared photos (Figure 2). This was used to demonstrate what could be done, how it was done and how it could be used.

From the Landsat CCT, and the utilization of our ORSER system, a set of output products was prepared to overlay the quadrangle. These included "N-Map", "U-Map", "U-Stats", "Stats", and "Class" products (Figure 3).

Conclusion

The result of these workshops has been increased awareness and the stimulation of specific interests. Several participants have

MORNING SESSION - Location - Room 228 Hills Building

8:30 a.m.	Introduction
8:45- 9:00	Electromagnetic Spectrum and Color Infrared Materials
9:00- 9:30	Anatomy of Color Infrared Films
9:30-10:00	Interpretation of Color Infrared Materials (slide presentation)
10:00-10:15	Coffee Break
10:15-11:00	Work with Color Infrared Materials
11:00-11:15	Overview of Photo Transfer Devices
11:15-12:00	Zoom Transfer Scope
12:00- 1:15 p.m.	LUNCH Given Cafeteria (Dutch Treat)

AFTERNOON SESSION - Location - 16 Colchester Avenue - Conference Room

1:15- 1:45 p.m.	Overview of LANDSAT
1:45- 2:15	Overview of ORSER System
2:15- 3:00	Orser Demonstration
3:00- 3:15	Coffee Break
3:15- 4:15	Hands on Experience by Interest
4:15- 4:30	Wrap-up Session

Figure 1. Sample syllabus of one day remote sensing workshops conducted for Vermont state agency personnel.

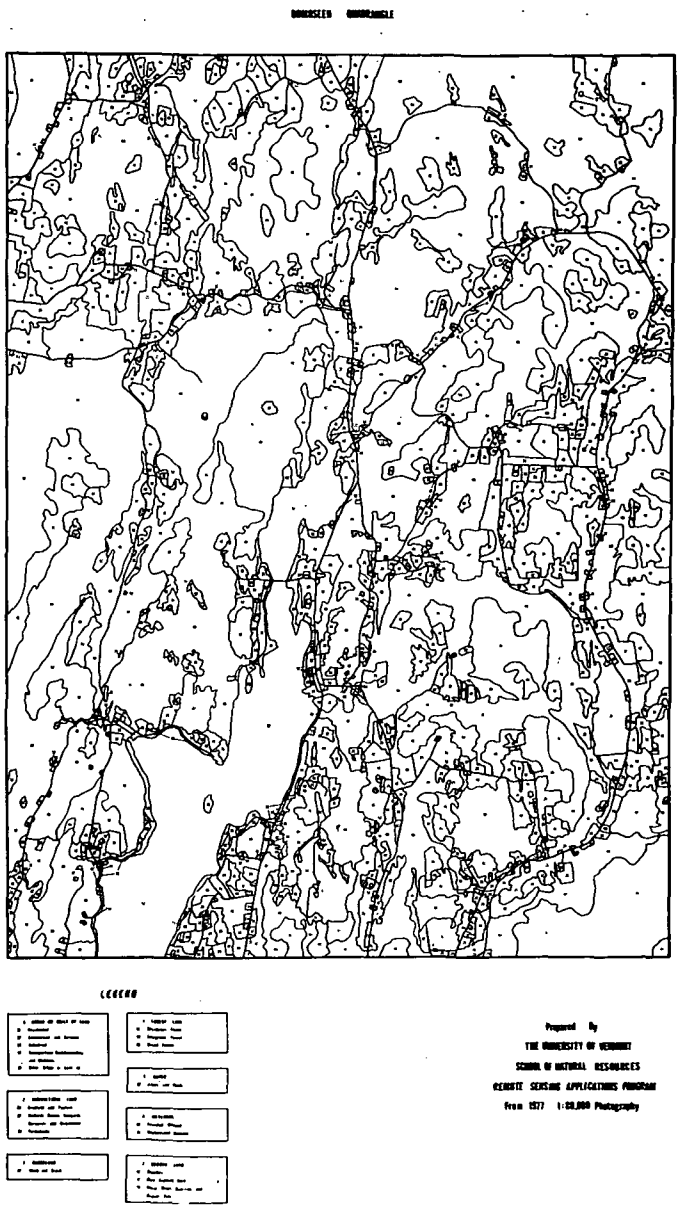

Figure 2. Land cover map of area covering the USGS Bomoseen quadrangle interpreted from 1977, 1:80,000, color infrared photography.

Figure 3. Land cover classification of USGS Bomoseen quadrangle produced by supervised classification using the "Class" program of the ORSER system. An overprint algorithm was developed to process this multi-colored line printer product.

requested additional information, returned for a "second look" and utilized the facilities to gain experience or to work on a problem of their own. Those who have returned have concentrated on the use of color infrared photography, optical interpretation and transfer equipment.

Resource managers who have had some formal training will continue to experience the need for additional training and technical assistance. The availability of resources to satisfy these needs is and will continue to be a major goal of our total program. Many of the applications projects which follow are the direct result of these educational activities.

Investigative Personnel

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SYSTEM DEVELOPMENT FOR DATA HANDLING AND ANALYSIS

Background and Objectives

At the inception of the Remote Sensing Applications Program, the School of Natural Resources made the commitment to evaluate and utilize all available sources of remotely sensed data. Existing capabilities were limited to traditional photographic interpretation techniques. With the grant from NASA (NGS 7453) the opportunity to expand into digital image processing was realized. Initial evaluation of available software packages, capable of processing digital data, such as Landsat were identified. Ultimately, the ORSER software package developed at the Pennsylvania State University was selected for installation on the University of Vermont's IBM 3031 computer. This decision was based on the programs' compatibility with existing computer equipment coupled with the fact that it could be purchased at a reasonable price.

Methodology

To assure the rapid installation of the software package, the School retained the services of the principal programmer for ORSER at Penn State. This consultant, working with local personnel, was able to bring up about 80 percent of the ORSER package in four days. The remaining programs were more specialized in nature and the decision was made to incorporate them as needed.

As the local user community became familiar with the capabilities of the ORSER programs, modifications were made in the programs to suit local needs. Of particular interest to the user community was the desire to produce better gray scale character maps without running classified output through another program. This capability has now been added to the package's euclidian distance classifier. Another time saving addition to the ORSER package was the interfacing of a Numonics digitizer

to the "SUBOUND" program. This allows the user to directly input line and pixel elements, which define the boundary of an irregularly shaped area. This has proven to be of considerable value in the analysis of lake and river watersheds. Numerous other modifications have been and will continue to be made to meet the needs of local users and to improve the capabilities of the ORSER package. The computer processing facilities of the School of Natural Resources are shown in Figure 3.

ORSER is principally a "batch" oriented system that requires considerable user knowledge. To aid the fledgling user, a file has been created for the system that is accessible to all and that explains the basic operation of the ORSER programs. Similarly a library file containing the names of all valuable data tapes, with descriptive information about each tape, is maintained for the user community. A copy of this tape library is shown in Table 2. Work is currently underway to make the ORSER package appear interactive by utilizing the capabilities of the CMS operating system of the IBM 3031 computer. The principal objective of this modification is to make the system more "user friendly", thus encouraging more individuals to utilize the system.

In addition to the development of a digital image processing capability, steps have been undertaken to improve our photo interpretation capabilities. This is vital to the overall success of the program, since some of the projects undertaken could not be carried out with Landsat data alone. These improved capabilities include the addition of two Bausch and Lomb Stereo Zoom Transfer Scopes and two Bausch and Lomb Stereo Interpretation Systems. Figure 5 illustrates one set of this equipment in the optical section of the remote sensing laboratory.

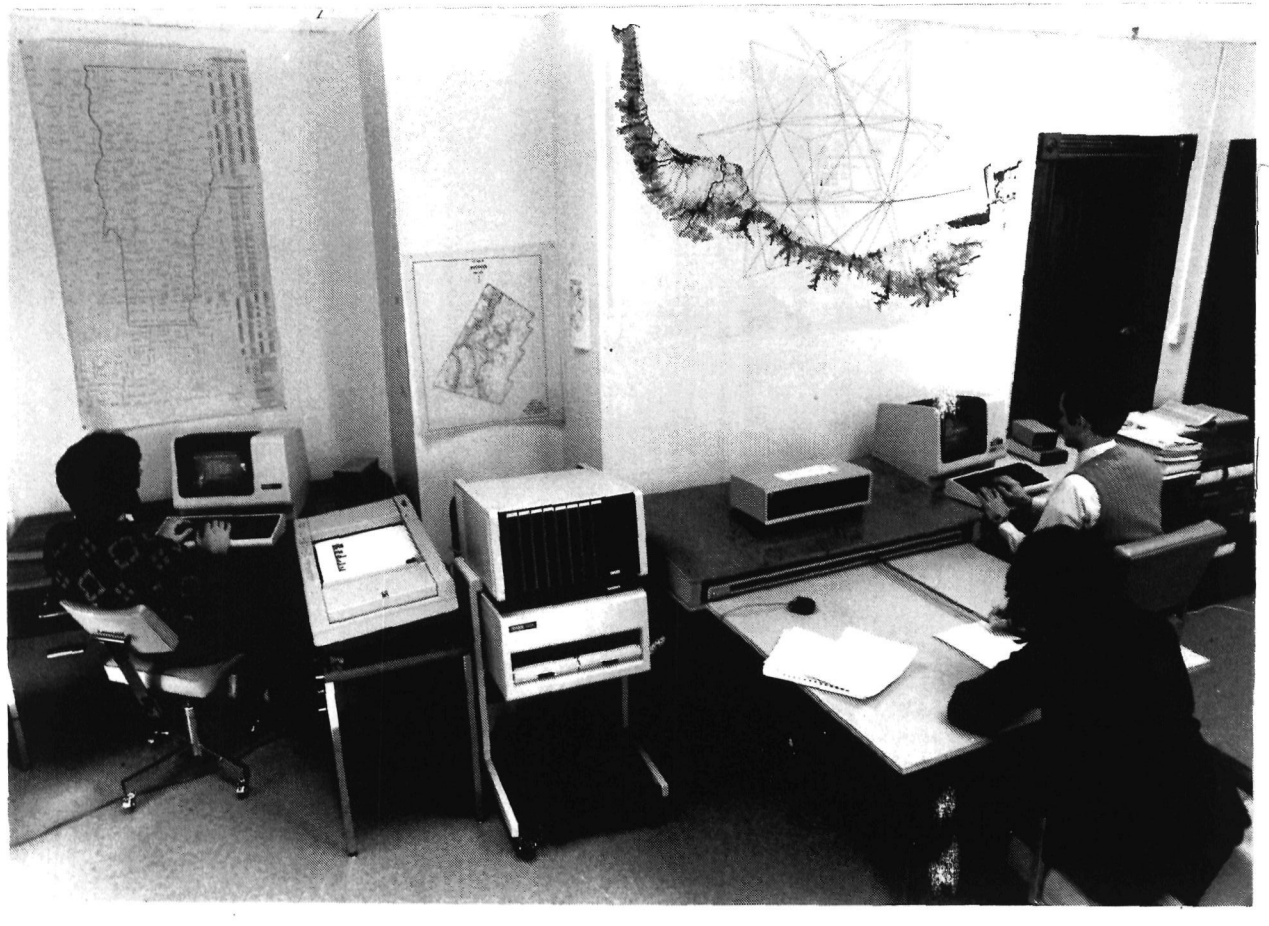

Figure 4. An overall view of the computing facilities of the School of Natural Resources.

Table 2. A listing of all available Landsat computer compatible tapes at Vermont. This library is maintained at the computer center and is available to all users of the ORSER image processing system.

TAPE LIBRARY

TAPE NAME	DATE	PATH	ROW	QUALITY	COMMENTS
SNR BLANK					THIS IS A BLANK WORKING TAPE FOR ANYONE TO USE.
SNR001	1 MAY 77	14	30	8888 0% CLOUD	FIRST 3 TRACKS ONLY. BANDS 4 & 6 EXPANDED TO 255 B.V.
SNR002	1 MAY 77	14	29	8888 0% CLOUD	BANDS 4 & 6 EXPANDED TO 255 BRIGHTNESS VALUES.
SNR003	3 JUN 76	24	29	8888 0% CLOUD	THIS IS A MICHIGAN TAPE
SNR004	26 SEP 78	14	29	8888 0% CLOUD	LANDSAT 3
SNR005	26 SEP 78	14	30	8888 0% CLOUD	LANDSAT 3
SNR006	1 MAY 77	14	29	8888 0% CLOUD	ALL 4 TRACKS NORMAL LANDSAT 2
SNR007	1 MAY 77	14	30	8888 0% CLOUD	ALL 4 TRACKS NORMAL
SNR008	27 OCT 72	14	30	8888 0% CLOUD	SCENE THAT IS IN MISSION TO EARTH
SNR009	10 OCT 72	15	29	8888 30% CLOUD	SCENE THAT IS IN MISSION TO EARTH
SNR010	22 AUG 78	15	29	8888 0% CLOUD	LANDSAT 3
SNR011	21 AUG 78	14	30	8888 0% CLOUD	LANDSAT 3
SNR012	22 AUG 78	15	30	8888 10% CLOUD	LANDSAT 3 THIS TAPE HAS TRACKS 2 - 4
SNR013	27 MAR 77	15	29	8888 0% CLOUD	LANDSAT 2
SNR014	29 AUG 73	14	29	8888 10% CLOUD	LANDSAT 1
SNR015	9 SEP 76	14	29	5888 10% CLOUD	LANDSAT 2
SNR016	9 SEP 76	15	29	8858 10% CLOUD	LANDSAT2
SNR017	2 NOV 78	15	29	8888 10% CLOUD	LANDSAT3
SNR018	6 MAY 78	15	29	8888 30% CLOUD	LANDSAT3
SNR019	21 AUG 78	14	29	8888 10% CLOUD	LANDSAT3
SNR020	21 JUL 78	15	29	8888 10% CLOUD	LANDSAT2 FIRST 2 FILES THIS TAPE IS GEO CORRECTED
SNR021	21 JUL 78	15	29	8888 10% CLOUD	LANDSAT2 SECOND 2 FILES THIS TAPE IS GEO CORRECTED
SNR022	14 NOV 78	14	29	8888 10% CLOUD	LANDSAT3 FIRST TWO FILES THIS TAPE IS GEO CORRECTED
SNR023	14 NOV 78	14	29	8888 10% CLOUD	LANDSAT3 FIRST TWO FILES THIS TAPE IS GEO CORRECTED
SNR024	18 OCT 74	15	29	8888 30% CLOUD	LANDSAT1

Figure 5. A part of the optical facilities of the remote sensing laboratory. Shown are a Bausch and Lomb Stereo Zoom Transfer and SIS-95 Stereo Interpretation System.

Conclusions

During the two year existence of the Remote Sensing Applications Program at the University of Vermont, considerable emphasis has been placed on system development for the analysis of remotely sensed data. Most notable has been the establishment of a digital image processing system, and subsequent user training for this system. The capabilities and user services provided through this continuing project have and will continue to benefit the university and the State of Vermont.

Investigative Personnel

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THE VERMONT LAND COVER CLASSIFICATION

Background and Objectives

The Vermont land cover classification was a cooperative Landsat demonstration project involving the Eastern Regional Remote Sensing Applications Center (ERRSAC), the Departments of Water Resources and Forests and Parks of the Agency of Environmental Conservation and the University of Vermont's School of Natural Resources.

The original objective of this project was to identify and map areas of defoliation by the forest tent caterpillar. The work was performed by an individual from Forests and Parks and one person from the University of Vermont, with the assistance of ERRSAC personnel. We were unable to accomplish the original objective due to lack of suitable Landsat scenes at the time of peak defoliation and a collapse of the insect population, producing lighter than anticipated defoliation. However, overall results of the general land cover mapping were very encouraging. The output products sparked considerable interest to attempt a complete LANDSAT derived cover type map of Vermont. A cooperative demonstration project was initiated and approved by ERRSAC.

Methodology

A prerequisite to the success of this project was the identification and acquisition of suitable Landsat data tapes. To completely cover the state required the classification and merging of portions of four Landsat scenes. With Vermont's chronic cloud cover, the selection of suitable data tapes was difficult. The decision was finally made to utilize two scenes recorded on September 26, 1978 (#30205-14555 and 30205-14561) for the eastern half of the state and another two scenes from August 22, 1978 (#30170-15011 and 30170-15014) for the western portion of

Vermont. All four of these scenes were cloud free over the state and had four good bands of data.

Ground truth information was collected and plotted on 1:80,000 color infrared photography from points around the state. As many forest types and crops as possible were located with the intention of producing a very detailed cover type map. Armed with a wealth of data to input into the IDIMS system, two people from Forests and Parks, one from Water Resources and two individuals from the University descended upon Goddard in the summer of 1979. This group remained there through the week attempting to grind out a very detailed cover map for the state. This task proved to be a very formidable one. It was compounded by the fact that the fall color change had begun to occur at the time the September 26 scenes were recorded. It became apparent that a more general map would have to be produced. The group left at the end of the week with map products for several 500 pixel by 500 pixel study areas. These study areas from around the state were taken back to Vermont to be examined in fine detail, to assure the accuracy of the classification. This work continued through the summer and into the fall.

In December 1979 two people from Vermont returned to Goddard armed with the necessary information to complete the classification. By the end of the week, the goal of completing the state was nearly realized. In early 1980 ERRSAC personnel delivered several large preliminary color prints of the classification to Vermont for final scrutiny. Following a few minor changes, the signatures to be utilized in the final classification were agreed upon by all contributing parties. All of the final production work, including the digitizing of the state boundary and merging of the four Landsat scenes, was performed at ERRSAC. The result of this work is shown in Figure 6.

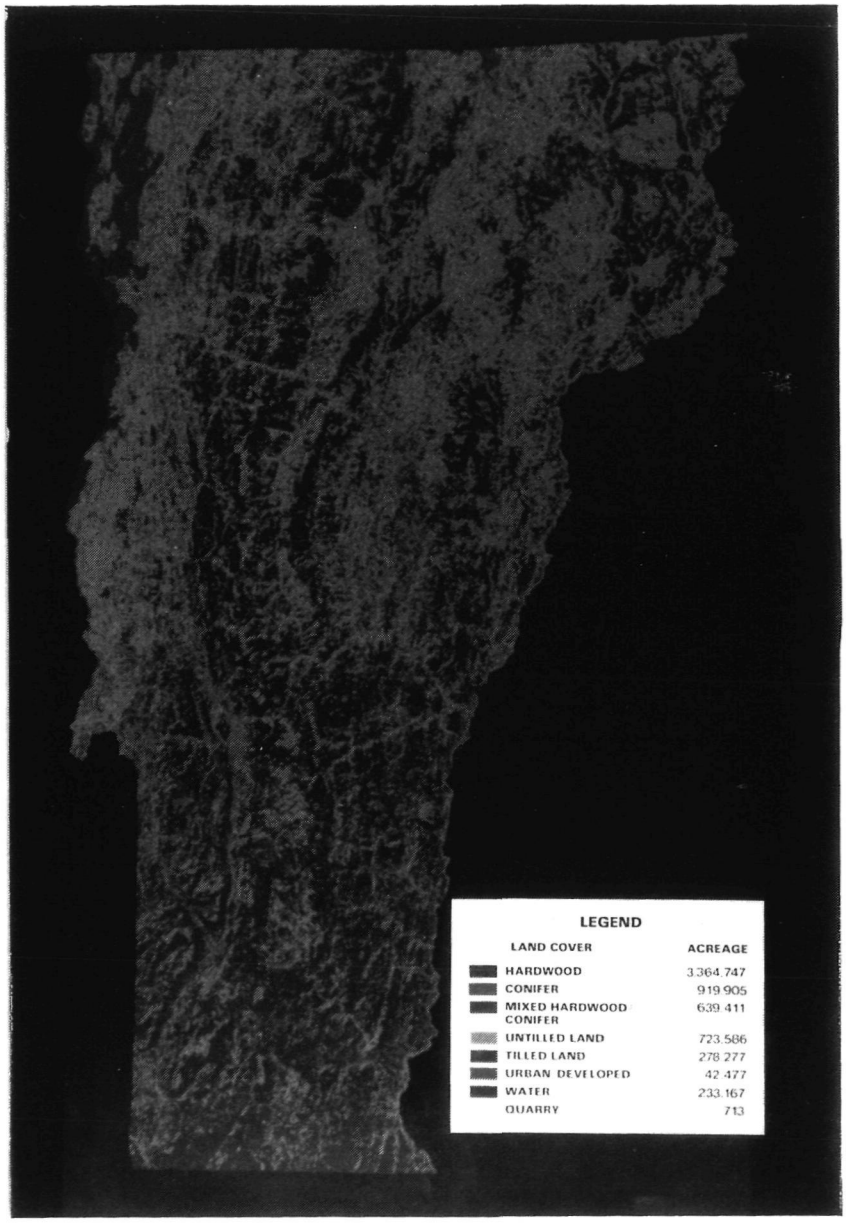

Figure 6. Land cover classification of the State of Vermont derived from the computer analysis of digital data of four Landsat scenes.

Conclusions

The results from this statewide cover type mapping project will be utilized in a variety of ways. The Department of Water Resources is currently utilizing the signatures developed at Goddard to produce cover type maps for the state's major lake and pond watersheds. The digitizing work is being conducted on facilities at the University of Vermont. Both the Department of Forests and Parks and the University would like to utilize the state classification as the first stage of a multi-stage sampling design to inventory the state's woodlands. The School of Natural Resources' Remote Sensing Applications Program has begun a sampling analysis to test the accuracy of the statewide classification.

The principal benefit derived from this demonstration project was the "jelling" of a general cooperative remote sensing effort within the state. With image processing capabilities available within the state and a general understanding of Landsat's capabilities held by many state officials, additional cooperative efforts can be anticipated.

Investigative Personnel

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A REMOTE SENSING APPROACH TO LAND USE CHANGE IN VERMONT

Background and Objectives

Agricultural/open land reversion in Vermont has historical roots which date back to the opening of free and/or inexpensive lands in the west in the 1850's and 1960's. This reversion of lands to a forest cover and more recently to "urban" uses could certainly affect the future agricultural and overall economic vitality of the state. Given the relative lack of both state and regional self-sufficiency and diversity, vulnerability to outside production and consumption becomes a critical issue. Energy, transportation, and labor costs associated with the dependence on extra-regional products are clearly felt by consumers in Vermont.

In addition, revegetation of agricultural land affects the attractiveness of Vermont to vacation travelers who enjoy mountain views and the rich contrast between farms, open pastures and forests. Agriculture plays and integral part in the rural character and culture of Vermont which draws important travel and recreation dollars to the state.

Knowing these facts, one can deduce that retention of agricultural/open land is intimately tied to Vermont's general economic vitality. But before addressing the issue of open land reversion and associated retention schemes, this change in land use must first be quantitatively identified.

Remote sensing is one effective means of identifying changes in land use. By employing a variety of remote sensing techniques the rate, location and type of change can be determined. Hence a greater understanding of underlying causes can be reached and subsequent work on effective means of dealing with the problem can be undertaken.

Methodology

The specific problem to be addressed by Remote Sensing Applications Program personnel in this study, therefore, involves the use of remote sensing in general and Landsat image processing in particular to identify and ultimately monitor agricultural/open land reversion at the local level in the state. Charlotte, Vermont, with a land area of 26,240 acres and bounded by Lake Champlain on its west side and the foothills of the Green Mountains to the east, served as the study area.

The research methodology for the study consisted of two components. First, preliminary land use change mapping was conducted with the aid of 1962 1:20,000 black and white and 1977 1:80,000 color infrared air photos. Photo-derived land use maps, which used 30 percent crown closure as the threshold between forest and agricultural land, were then overlayed on and a "change" map created. Figures 7, 8 and 9 are illustrations of these maps. This procedure had as its primary objective the provision of an accepted, established base for comparison with Landsat capabilities.

Computer processing of Landsat data using Penn State's ORSER software package comprised the heart of the study. Initially a six year time span from 1972 to 1978 was designed to test the applicability of Landsat in detecting agricultural/open land reversion in Charlotte. Following this second analytical step, a methodology was to be developed for conducting similar studies for other interested parties in the state.

Study results succeeded in clearly demonstrating the variability which exists in the physical characteristics of Landsat imagery as well as with the ORSER software system. An August 28, 1978 scene (#30170-15011) had to be merged with a May 1, 1977 scene (#0830-14362) in order to better differentiate categories which were too spectrally similar when using the August scene alone.

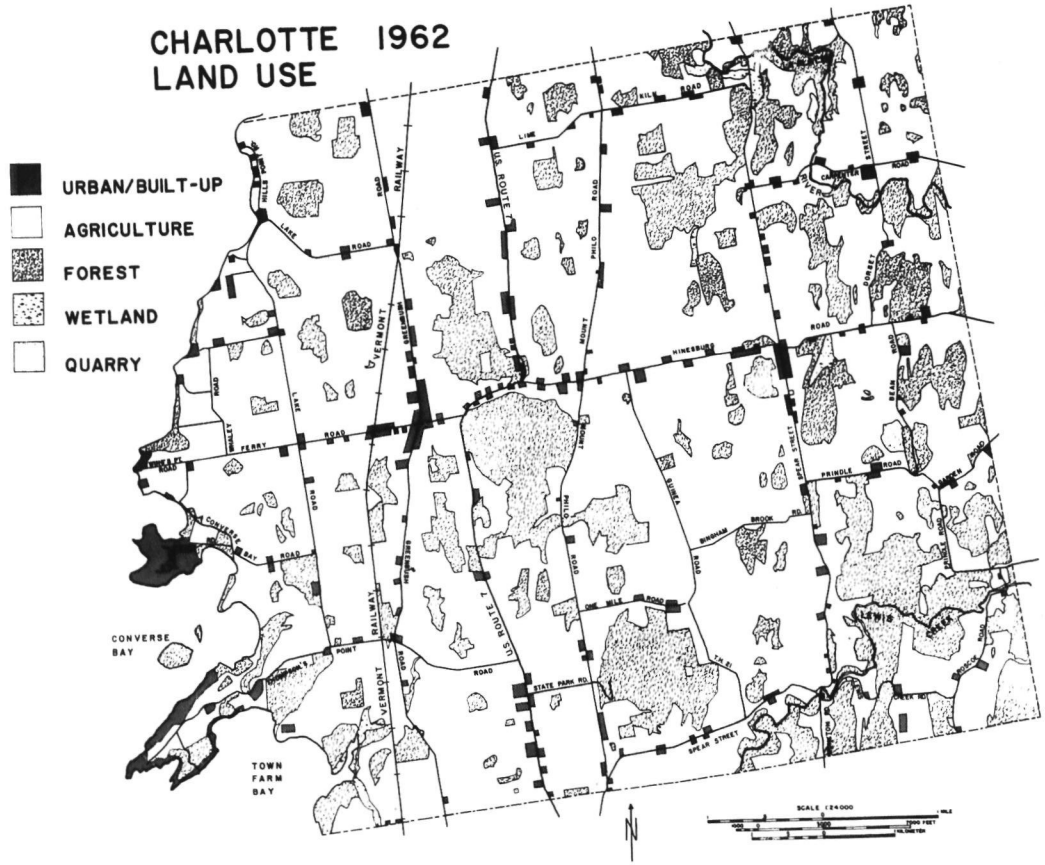

Figure 7. Land use map of the Town of Charlotte, Vermont interpreted from 1962 black and white panchromatic photography.

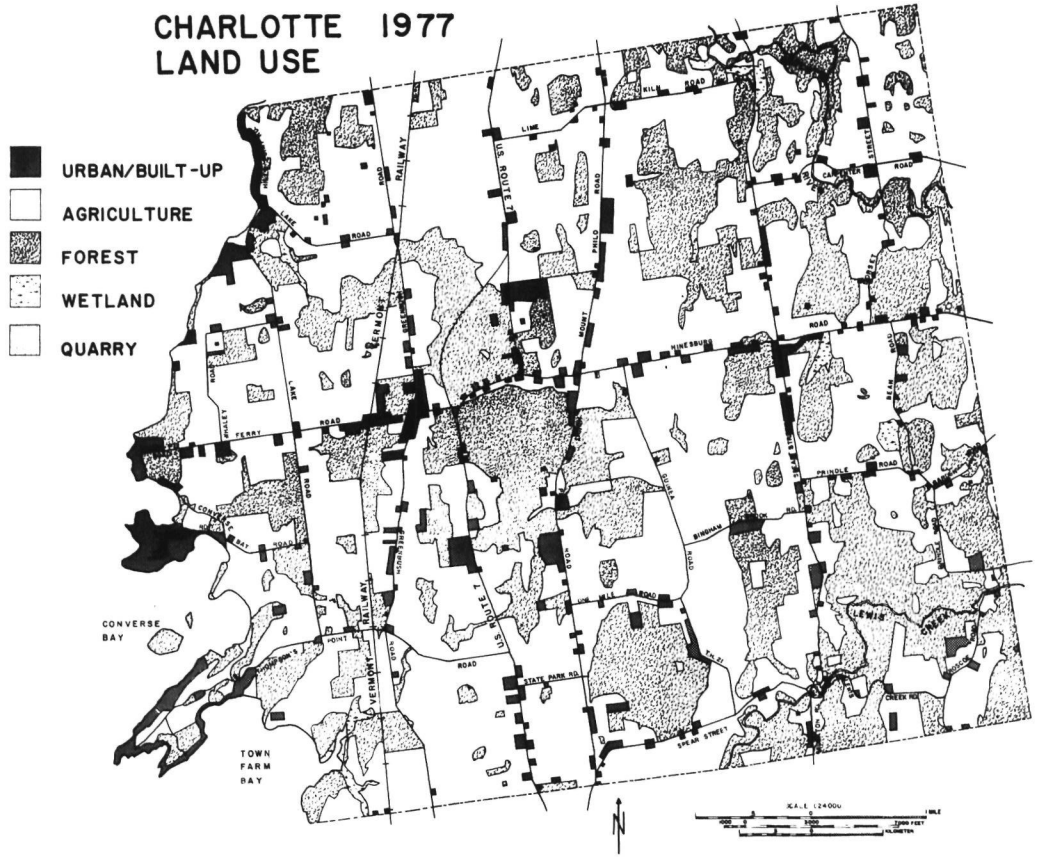

Figure 8. Land use map for the Town of Charlotte, Vermont interpreted from 1977 color infrared photography.

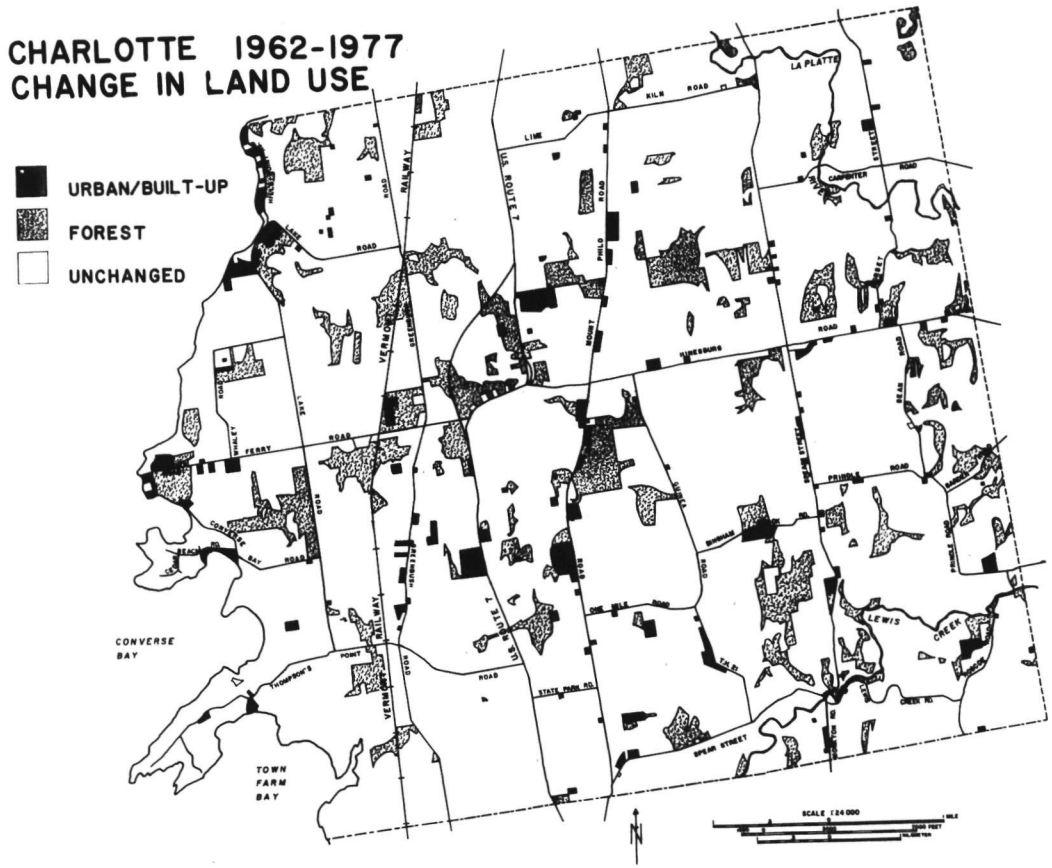

Figure 9. A map of Charlotte, Vermont shwoing the changes in land use that occurred between 1962 and 1977.

Analysis of an early date for comparison with the 1978 classification developed into a futile venture. The October 10, 1972 scene (#1079-15115) presented classification problems due to the spectral similarity of agricultural lands and some hardwood forest areas at that time. An August 29, 1973 scene (#1402-15053) was eventually eliminated from the analysis when it was determined that extensive and uneven atmospheric scattering made accurate classification impossible.

Finally, merged data from September 9, 1976 and May 1, 1977 were tested in an attempt to arrive at the second classification needed for analysis. It was at this point that the limitations of the ORSER system became quite apparent. The supervised data analysis program MAXCLASS, which had been determined to be the best classifier, failed to run on the signatures developed for the merged data despite repeated efforts to do so.

In addition, the rubber sheet stretch program, RUBRFUN, was unable to properly register the two classifications. Proper registration is essential to the comparison of two dates and RUBRFUN was unable to adequately do so.

Conclusions

The study concluded that based on comparison of a good 1978 classification with the change identified from the air photo analysis, Landsat was able to detect little of the photo-derived change. Recently reverted fields displayed a signature which was too close to pasture to be able to differentiate between the two. It became apparent that the 30 percent crown closure threshold used in the air photo classification was inappropriate for Landsat analysis. Since agricultural/open land reversion is assumed to be continuous and cumulative over time, perhaps

a larger time span than six years would aid in identifying reverted fields at a later stage in development.

Along with the enhanced possibilities of such a project when conducted over greater time span, one must be aware of the necessity for good, usable Landsat scenes that are from optimum seasons in a spectral sense. Also the vagaries of parts of the ORSER system need to be ameliorated before thorough change analysis can be conducted. It should be pointed out that a new rubber sheet stretch routine has been developed by Penn State since this project was completed.

Finally, an exciting future for the Landsat system includes the thematic mapper which will be capable of 30 meter resolution. It should improve the likelihood of success for a change detection project such as this where changes are subtle and forest infringements on agricultural lands often incremental.

Investigative Personnel

Jeffrey J. Harris, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Research Assistant, Burlington, VT.

LAND COVER/USE CLASSIFICATION FOR PLANNING

Background and Objectives

This project is being conducted under the leadership of the Central Vermont Regional Planning Commission (CVRPC) with the cooperation of the Valley Area Association. The primary objective of the ongoing project is to provide a basis for long range planning and management decisions concerning economic diversification in the Valley. Presently the area is heavily impacted by the presence of the very large Sugarbush Valley Ski Area, the somewhat smaller Mad River Glen Ski Area, and associated commercial development. Consequently, employment in the Valley is seasonal and the derived income generally low. A large recreational facility such as Sugarbush Valley, which is becoming a designation resort, is a tremendous growth inducer that is infringing upon the natural resource base. Scattered residential and commerical developments threaten productive agricultural lands and other sensitive or important lands.

Methodology

The role of the School of Natural Resources, Remote Sensing Applications Program personnel in this impact study was to provide land use information for the towns of Warren, Waitsfield and Fayston interpretated from 1977 1:80,000 color infrared photography. In some cases this required classification to level IV. The interpreted data were transferred to 1:24,000 base maps with a Bausch and Lomb Stereo Zoom Transfer Scope. An acreage summary for each cover type was prepared with the maps and submitted to the Central Vermont Regional Planning Commision. Photo interpretation work for the 68,544 acre project was funded in part by CVRPC, which contributed $500. Figure 10 shows the land use map for the town of Waitsfield.

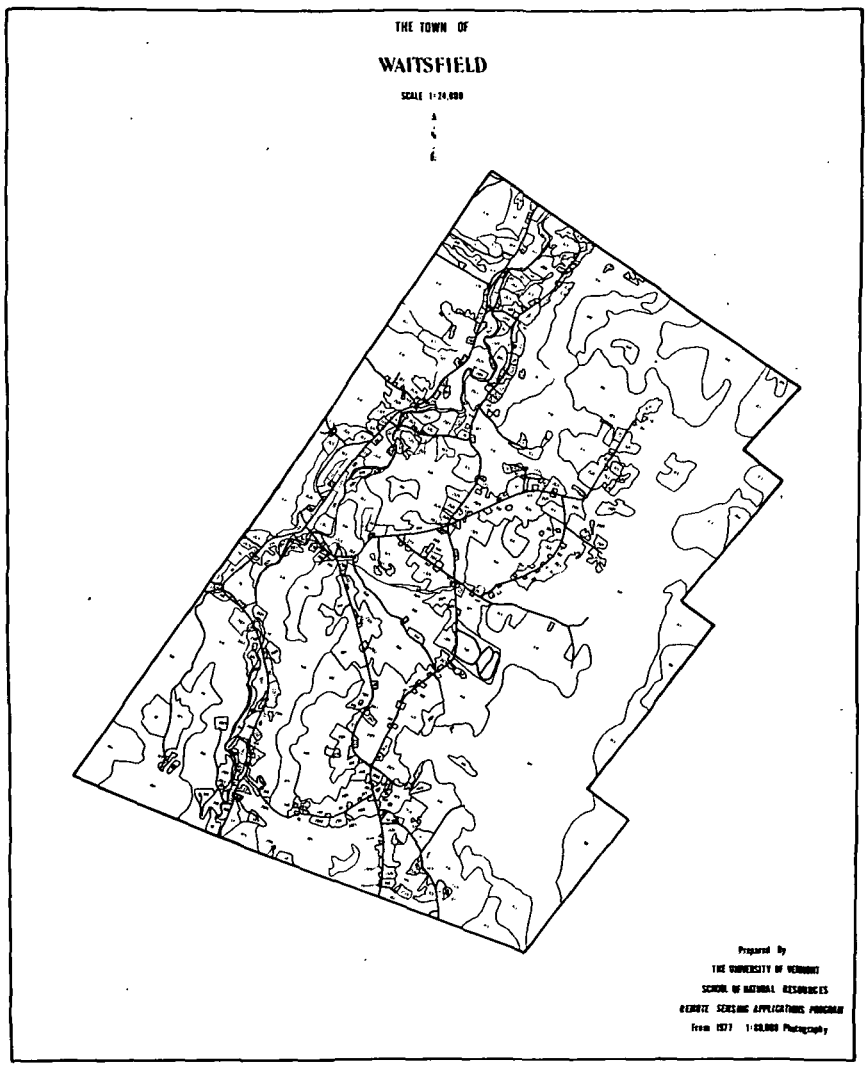

Figure 10. Land use map of the town of Waitsfield, VT interpreted from 1:80,000 color infrared photography and transferred to a 1:24,000 base map.

Conclusions

While the Mad River Valley Impact Study is an ongoing one, a number of uses for the map series have already emerged. First, the maps have been routinely incorporated into the writing of town plans for Warren, Waitsfield and Fayston. Revisions in zoning bylaws have been based in part on these maps as have reviews of development proposals. Our most recent contact with CBRPC revealed the use of the maps in aiding in site location for a prospective industrial plant.

In conclusion, it is apparent that the work provided by the School of Natural Resources Applications Program has resulted in a number of local planning and management decisions in the Mad River Valley and that the information will continue to be used in the future. This project is also important in that it demonstrates to a number of potential regional and local users the value of remote sensing in aiding resource planners and decision-makers.

Investigative Personnel

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

REMOTE SENSING INVENTORY AND INFORMATION SYSTEM

Background and Objectives

The Remote Sensing Information System (RSIS) is a micro computer based data bank containing descriptive information on aerial imagery obtained over the State of Vermont. Envisioned as a prerequisite to an efficient and effective remote sensing applications program, this information has become a valuable resource to individuals, organizations and agencies across Vermont. Until the creation of this data bank, no single source for this information existed.

Methodology

To begin the data collection process, requests for information on Vermont photography were sent to government archives and to aerial photo survey firms located in the northeast. In addition, inquiries were sent to all groups, organizations and agencies within the state who were considered possible users of aerial photography. The purpose of this mailing was to identify all photo flights conducted over the state and to discover the owners of copies of this photography. These mailings were followed up with phone calls to clarify certain information and to seek the assistance of those who had not responded to the questionnaire. Finally, personal visits were made to as many sites as possible across the state to view the photography and help assure the accuracy of the information included in the data bank.

This extensive search revealed that over 200 separate photo missions have been conducted over the state. Initial plans had called for the publication of this data in a booklet format. This idea was dropped in favor of a more suitable distribution plan when it became apparent that this booklet would be out of date shortly after it was printed. A more

suitable solution is to enter the data into a computer and then to selectively add, correct and retrieve information as required. A similar system is employed by the EROS Data Center to store descriptive information for Landsat scenes.

The computer programming necessary to house, edit and retrieve these data is being performed on a Digital Equipment Corporation 11/03 micro computer with dual floppy storage disks. All operations of RISIS are interactive and designed to be very user friendly. To operate the system, the user is first presented with a menu of available options. A display of this menu, as it appears on the terminal, is shown in Figure 11. To begin operation of the system the operator enters the number associated with the function he wishes to perform. From this point on the system will prompt the user for additional required information. At the present time, only the data entry portion of the system has been completed.

To notify all potential users of the existence of the data bank, a brief pamphlet is being prepared describing the system. Because many of the potential users have had little experience in the use of remotely sensed data, a brief discussion of remote sensing, photo scale, film types and suggested uses for the imagery is included. This material was added with the intent of attracting new users, such as town officials, to the idea of using remotely sensed data. An order blank is included at the end of this pamphlet for the user to complete and return to request information. A copy of this form is shown in Figure 12.

The data has been entered into the computer so that they can be selectively withdrawn to meet specific user reuqirements. Upon receipt of an inquiry, a search will be made through the files to identify all suitable imagery. Coverage can be requested by specific town, county

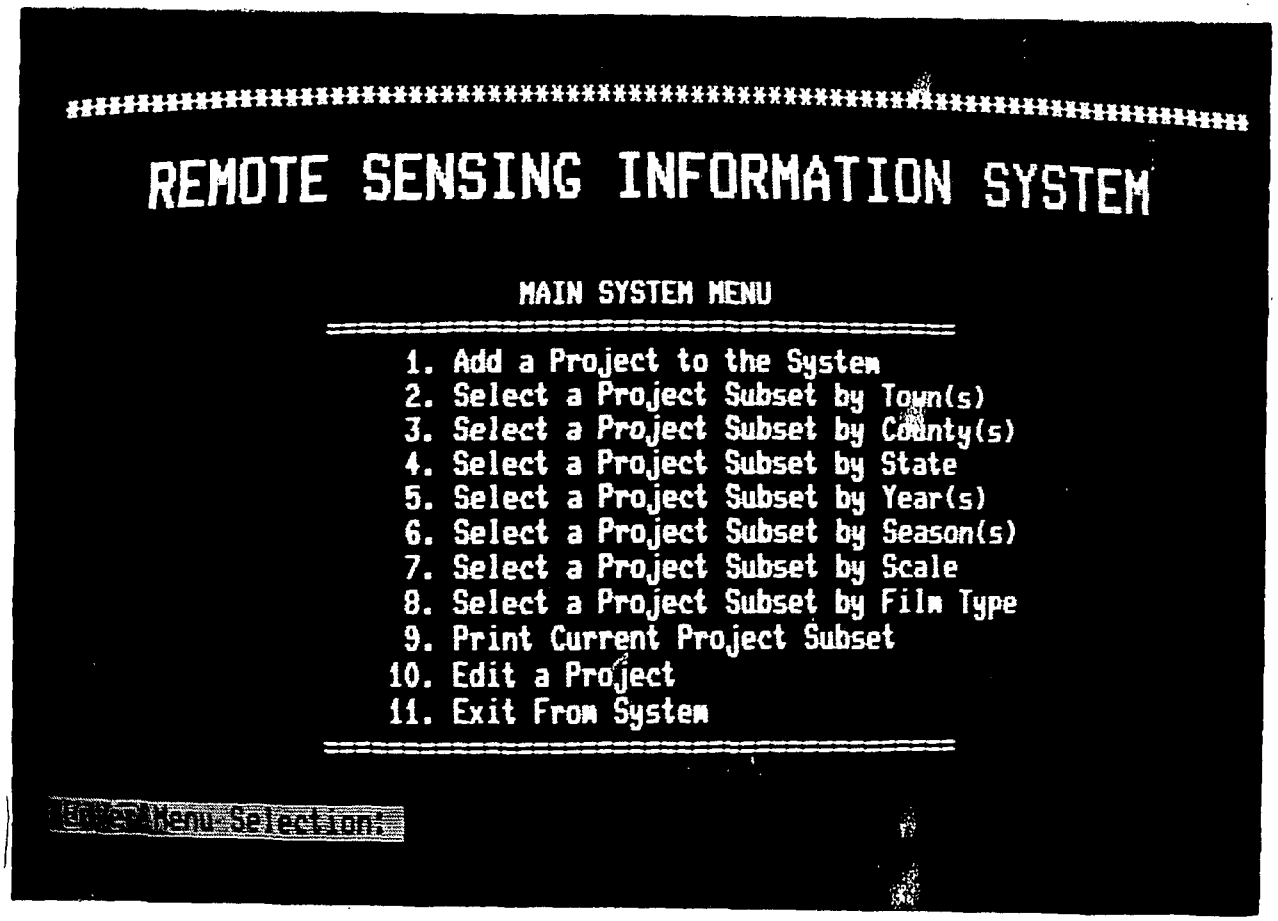

Figure 11. The menu, as it appears on the computer terminal listing the available operations of the Remote Sensing Information System.

VERMONT REMOTE SENSING DATA BANK INQUIRY SHEET

1. Geographic area of interest. (Specify by town(s) or county(s)).

_____

_____

2. Scale or Range of acceptable scales
   i.e., 1:15,840 to 1:24,000

   _____ to _____

3. Film type (check appropriate boxes)

   Black & White /__/ Black and White Infrared /__/

   Color /__/ Color Infrared /__/

   All film types /__/

4. Date or Range of dates by year
   i.e., 1976 or 1970 to 1980

   _____ to _____

5. Season of the Year (check appropriate boxes)

   Spring /__/ Summer /__/

   Fall /__/ Winter /__/

6. Planned use of the imagery:

_____

_____

_____

_____

Figure 12. An inquiry sheet to be submitted by individuals, groups and agencies requesting information contained in the Remote Sensing Information System.

or for the entire state. Additional constraints, such as film type, scale or range of scales, year and season can be placed in the search. For example, an individual could request all of the coverage obtained over Burlington between 1953 and 1957 utilizing black and white panchromatic film at a nominal scale of 1:20,000. With such a request the inquirer will be furnished a list typed by the computer containing all of the photo projects meeting his specifications. Along with this list will be included specific information about each flight such as its initial purpose, who holds the negatives, how copies can be obtained and who holds copies of the photography within the state. A small state map will also be included for each project indicating the approximate boundaries of the flight.

Conclusion

By structuring the data bank around the information handling capabilities of a computer, the Remote Sensing Information System will remain a current data source for years to come. With this data bank, the School of Natural Resources' Remote Sensing Applications Program will be able to provide a needed data source to the people of Vermont.

Investigative Personnel

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Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

Roy A. Whitmore, Jr., University of Vermont, School of Natural Resources, Department of Forestry, Professor and Chairman, Principal Investigator, Burlington, VT.

LAND COVER/USE CHANGE FOR WATERSHED MONITORING

Background and Objectives

The LaPlatte River Watershed, an area of approximately 36,740 acres located in Chittenden County, is the focus of a twelve year project designed to achieve watershed protection and water quality improvements. Along with the participation and support of local farmers, the study is the cooperative effort of three groups: the U.S. Department of Agriculture, Soil Conservation Service; University of Vermont, Vermont Water Resources Research Center; and the Winooski Natural Resources Conservation District.

The major concerns of this study are the farming methods and the means of disposing of manure currently in use in the LaPlatte River watershed. Various farming practices, such as continuous corn production, insufficient crop rotation, overgrazing of pasture lands, have accelerated soil erosion in the watershed. These have resulted in adverse consequences, such as reduction in the soil fertility, reduction in crop quality, and deterioration of water quality of the river by contributing to algae and weed growth.

As selected "Best Management Practices" are implemented, the water quality of the LaPlatte River and Shelburne Bay (Lake Champlain) should begin to show evidence of improvement. A program for monitoring changes in water quality will be directed by the University, Vermont Water Resources Research Center. This monitoring program is designed to establish relationships between the forms of phosphorous present in surface waters and differing and changing agricultural usage.

Since this watershed project was initiated at approximately the same time in the early stages of ORSER system development, it was appropriate for the Remote Sensing Applications Program to provide the necessary

baseline data on land use. Along with ORSER system development, this project was to serve as a demonstration of the capabilities of both Landsat and conventional aerial photography in classifying and potentially monitoring changes in land use over time.

Methodology

Photo interpreted maps were prepared with the aid of the 1977 1:80,000 color infrared photography and transferred to a 1:24,000 base map with a Bausch and Lomb Stereo Zoom Transfer Scope.

Landsat data used for classification on the ORSER system was comprised of two merged scenes, May 1, 1977 (#0830-14362) and August 22, 1978 (#30170-15011). This procedure was undertaken to improve classification accuracy and to test several ORSER programs. Figure 13 illustrates the ORSER-derived classification for the watershed.

Comparison of the Landsat classification and photo-derived classification, when aggregated to Level I, show that the Landsat accuracies range from 84 percent (forested lands) and 96 percent (agricultural lands) to a low of 15 percent for wetlands and 54 percent for water. Some of the discrepancy between the two classifications may be attributed to the 8 percent of total land area being classified as "urban and built-up" on the photo-derived map and absent from the Landsat classification. As a result, agricultural and forest lands were over-represented on the Landsat classification.

Conclusions

This demonstrated project has provided useful baseline data of land use at the onset of the LaPlatte River Watershed Project. In addition, the potential for ongoing monitoring of agricultural land use within the watershed in future years using remote sensing techniques has

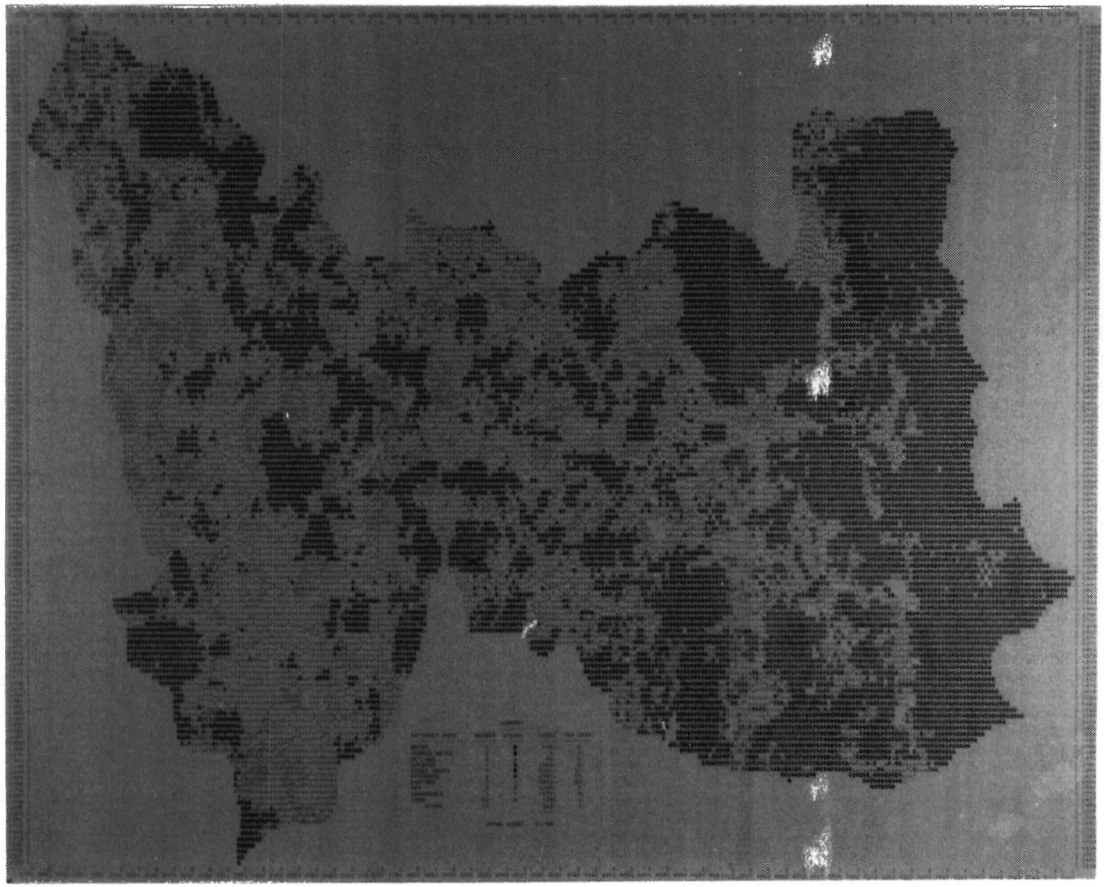

Figure 13. Landsat dervied land cover map of the LaPlatte River watershed produced using supervised classification on the ORSER system.

been established. Finally the demonstration was useful to project personnel for training in the development of image registration, data merging, and classification procedures on the ORSER system.

Investigative Personnel

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

FOREST INSECT DEFOLIATION DETECTION

Background and Objectives

The extent of defoliation of hardwood forests in Vermont caused by infestations of forest tent caterpillar and other defoliators has increased dramatically in recent years. It is estimated that the recurrent infestation affected 10,000 to 30,000 acres in 1978. Defoliation causes economic loss by reducing annual growth and increasing tree mortality among preferred species such as sugar maple. Regulatory agencies, in this case the Vermont Department of Forests and Parks, must have timely, accurate and efficient methods of detecting and mapping the defoliation.

The objectives of this study are to develop and evaluate techniques for monitoring the intensity and distribution of defoliation by forest insects in west central Vermont. This study is a continuation of a previous study undertaken jointly by ERRSAC, The University of Vermont and the Vermont Department of Forests and Parks. The previous effort was unsuccessful because of a virus infection of the forest tent caterpillar population resulting in greatly reduced defoliation which was not detectable by Landsat.

Methodology

Heavy populations of forest tent caterpillar and gypsy moth were reported in Rutland County, Vermont prior to defoliation as determined from egg mass counts in sample areas. This made the area particularly attractive for this test application of Landsat data. The plan called for field mapping of defoliation at or near peak by field personnel of the Vermont Department of Forests and Parks. Mapping involved both ground and aerial reconnaissance. Field observations were transferred to recent black and white panchromatic and color infra-red aerial photography. Timely Landsat imagery of path 15, row 29 was acquired covering

the study area. Suitable cloud free imagery was obtained from the July 19, 1979 pass (#21641-14540). Utilizing the base maps and other ground truth sources, specific infected areas were located and subset from the data tapes. The data sets were geometrically corrected and scaled to overlay the 1:24,000 USGS Bomoseen quadrangle. Overlays of defoliated areas were also prepared at the same scale.

From this geometrically corrected data, "N-Maps" (brightness) and "U-Maps" (uniformity) were generated for the selection of training sites. These were used to develop unique signatures for defoliated areas. The signatures were developed using the "U-MAP" and "U-STATS" programs. Mapping symbols were assigned to the categories derived from the above programs and a character map generated for the Bomoseen test site. For the limited test area, the classification agreed closely with ground truth data.

However, when the classification was applied to a larger area, much disagreement was noted. Lack of or sketchy ground truth did not permit further checking of the extended classification. At the same time transfer of state personnel precluded further ground truthing of the study area.

Conclusions

These limited results indicate that LANDSAT data can probably be used to detect defoliated areas provided that the imagery is acquired at periods of peak defoliation. Sufficient and accurate ground truth is essential. Further tests are planned for the coming season and will incorporate color infrared photography over the test sites.

Future test applications should incorporate image differencing techniques with geometrically registered "before" and "after" scenes over specific sights. This approach should be explored although it may

have practical limitations due to the availability of suitable imagery within the necessary time frame.

Investigative Personnel

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

Brent Teillon, Agency of Environmental Conservation, Department of Forests, Parks and Recreation, Forest Resources Protection Division, Chief, Montpelier, VT.

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LAKE AND POND WATERSHED COVER MAPPING

Background and Objectives

An outgrowth of the Vermont statewide Landsat classification was the desire by the State's Department of Water Resources to cover type map major lake and pond watersheds in the state. This large undertaking was outside the scope of the state land cover demonstration project, conducted in cooperation with the Eastern Regional Remote Sensing Applications Program (ERRSAC), and would have severely taxed the personnel and facilities in Maryland. For this reason the Department of Water Resources approached the University's Remote Sensing Applications Program for assistance. The Department proposed to do most of the work with their own personnel, thus improving their own expertise in Landsat processing.

Methodology

Having previously demonstrated the capability of the ORSER system at the University to effectively map watersheds, the Remote Sensing Applications Program offered its facilities and assistance to the Department of Water Resources. The signatures that were defined at ERRSAC for the state land cover classification were transferred to Vermont and utilized on the ORSER system.

Much of the work was performed at the Department of Water Resources' office in Montpelier by remotely accessing the ORSER system by phone line. Technical assistance and instruction in the use of ORSER was provided by the Remote Sensing Applications Program. Digitization of the watershed boundaries was performed on the School of Natural Resources' digitizer through interface developed by the program staff.

At the completion of the project, over 300 watersheds and subwatersheds will be mapped. The data derived from this project will be utilized as baseline data for monitoring change over long periods of time.

Conclusions

Through this project, a good working relationship has developed between the Department of Water Resources and the School of Natural Resources. This has led to the planning and development of several cooperative projects utilizing remotely sensed data. The actual execution of these additional projects is awaiting appropriate funding. By participating with the Department of Water Resources, the Remote Sensing Applications Program has moved one step closer to establishing itself as a state and regional center for remote sensing activities.

Investigative Personnel

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Alan R. Patunoff, Agency of Environmental Conservation, Biomatrician, Montpelier, VT.

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

Eric Swanson, Agency of Environmental Conservation, Department of Water Resources, Lakes and Ponds Program, Research Technician, Montpelier, VT.

LANDSAT LAND COVER CLASSIFICATION FOR 19 RIVER WATERSHEDS IN VERMONT

Background and Objectives

This demonstration project was initiated in the Spring of 1980 with the Soil Conservation Service (SCS) with the objective of utilizing Landsat data processing in classifying over 1.2 million acres of land in 19 watersheds in Vermont. This project is being carried out by the School of Natural Resources Remote Sensing Applications Program, with funding for computer costs and supplies to be supplied by SCS.

As part of the SCS non-point pollution program, approximately 25 percent of the farms in each of the 19 watersheds have undergone 100 percent sampling of parameters such as crop rotation, number of animals, manure management techniques, percent slope, length of slope, and amount of pasture and cropland acreage necessary for determining erosion rates. The role of the Landsat classification in this scheme is to supply a summary of land use and to provide the data necessary for what the SCS calls an "expansion factor" by which the sampled acreages of tilled and untilled (and associated parameters) can be confidently projected across each watershed.

Methodology

With the objective of separating tilled and untilled agricultural lands in mind, two May 1, 1977 scenes (#0830-14365 and #8030-14362) were selected for analysis. A spring date was chosen because the spectral differences between the bare soil of tilled land and grassy vegetation on untilled agricultural land is maximized. Preliminary checks on classification accuracy of the watersheds will be conducted with the aid of 1:80,000 color infrared photography flown in October, 1977. The SCS office in Burlington, Vermont will then conduct additional checks on the classification accuracy.

The first watershed, Malletts Bay, has been completed at a scale of 1:24,000 using the standard supervised classification procedures available on the ORSER system. Figure 14 shows the location of the 19 watersheds in the state and Figure 15 shows the land cover classification for the Malletts Bay watershed classification. It is apparent that some conflict exists between the urban and tilled land categories in the May scene because of the spectral similiarity of concrete, rooftops, and other urban features and the bare soil of tilled lands. Fortunately, in a rural state such as Vermont this problem has minimal significance outside of the Burlington area and appropriate "cleaning" techniques can be used to eliminate it.

Conclusions

Results of this preliminary work are encouraging. Aside from a few areas of conflict with urban lands, Landsat appears to be an appropriate sensor for separating tilled and untilled agricultural lands. The potential for ongoing land use classification and monitoring projects, with additional funding by SCS will hopefully increase when the accuracy and speed of classification with Landsat data are subjected to cost-benefit analysis.

Investigative Personnel

Jeffrey J. Harris, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Research Assistant, Burlington, VT.

Lawrence Knight, USDA Soil Conservation Service, Civil Engineer, Burlington, VT.

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

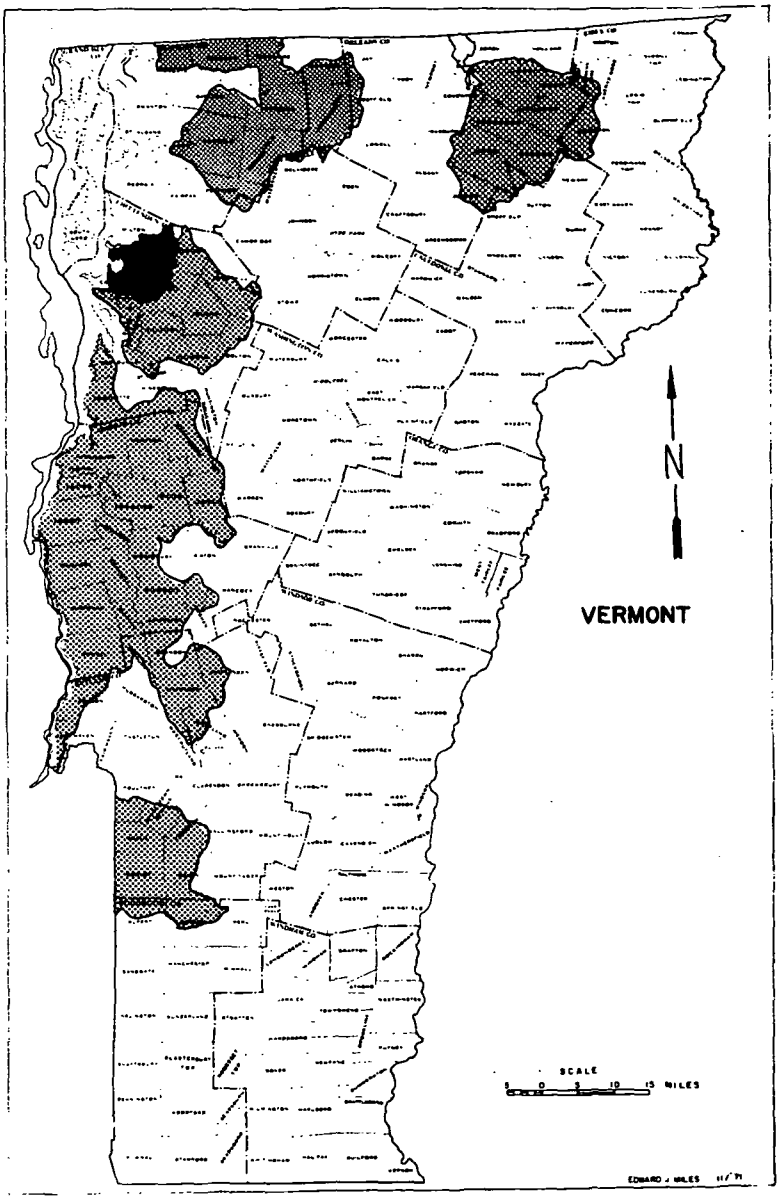

Figure 14. Major river watershed locations in western and central Vermont. The dark shaded watershed is the Malletts Bay watershed.

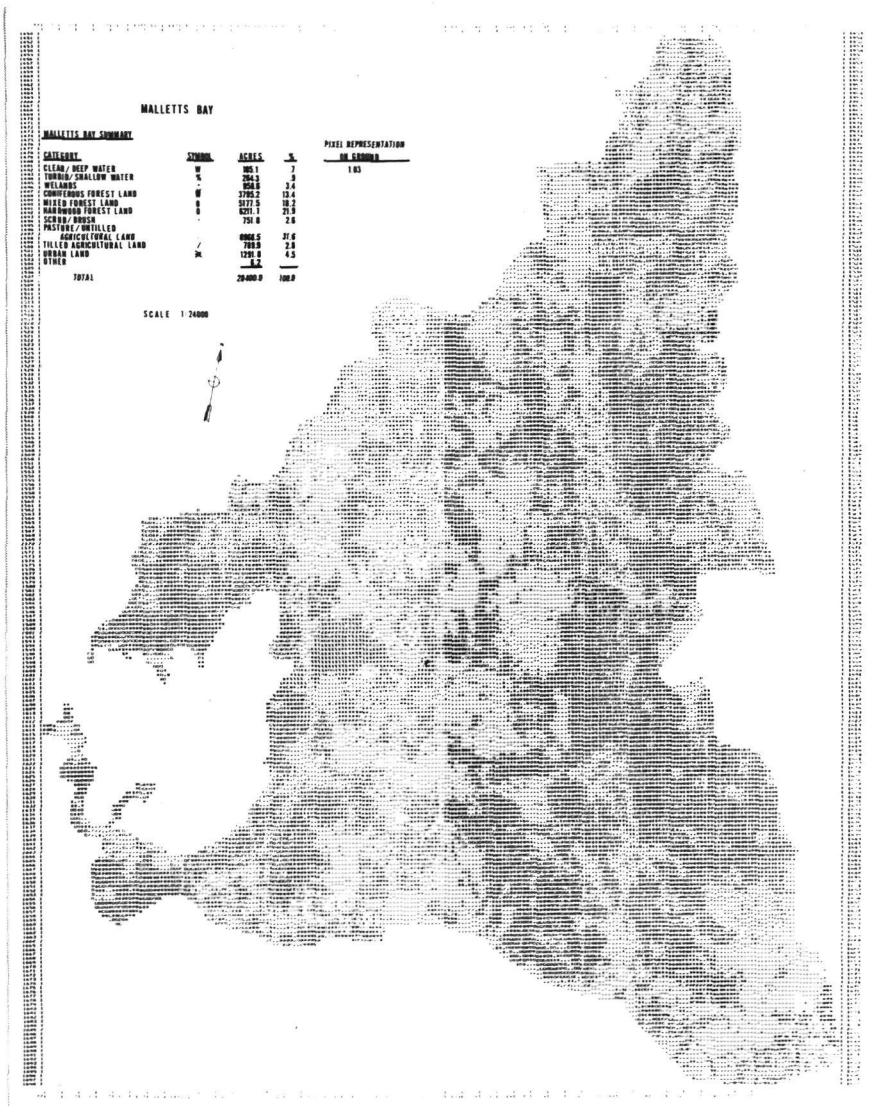

Figure 15. A cover type map of the Malletts Bay watershed derived from Landsat data acquired on May 1, 1977.

CONIFEROUS SPECIES DIFFERENTIATION

Background and Objectives

Forest land managers in Vermont are faced with the challenge of producing more wood over shorter periods of time on a fixed land base because of increasing demands for wood and wood fiber products. Over the past fifty years, thousands of acres have been planted to native and exotic coniferous species. Up to date inventories, even those as simple as species identification and location, are at best fragmented.

This study was undertaken to see if remote sensing techniques using Landsat imagery could provide a reliable and economic means of obtaining inventory information regarding the type and location of artificially regenerated coniferous forest stands.

Methodology and Results

The area selected for study was a portion of the Essex Town Forest located four miles east of Essex Junction, Vermont. Several large plantations of red, Scots and white pine were planted about 40 years ago. The site is level and is characterized by a uniform soil type. Stand density, as measured by crown cover, is 90-100 percent for all of the plantations. Ground truth was provided from interpretation of 1974 1:20,000 black and white panchromatic and 1977 1:80,000 color infrared photography and on site checks. Areas and species of each plantation were delineated on overlays of the above photography and transferred to a 1:24,000 base map which overlaid the 7½ minute USGS Essex Junction quadrangle using a Bausch and Lomb Stereo Zoom Transfer Scope.

The Landsat data sets used to meet this objective were subset from September 26, 1978 (Path 14 Row 29 #30205-14555) and May 1, 1977

(Path 14 Row 29 #20830-14362) scenes. All processing was done using the ORSER system as installed on the University's IBM 3031 computer. The subsetted data were geometrically corrected and scaled to overlay the 1:24,000 base map using control points that could be accurately located on the base map and an "N-MAP" line printer map of the reformated CTT data.

Using the September 26, 1978 data set, training sites within each species block were selected and histograms and statistical output for the training sites were run. No separation in MSS bands 4, 5, 6 or 7 was evident.

Foresters have noted that Scots pine exhibits a tendency to "yellow off" during late winter and early spring prior to bud break. This phenological characteristic is probably due to changes in pigment proportions. Bud break for most conifers in the Champlain Valley occurs during the first two weeks of May. The May 1, 1977 data set was obtained prior to this event when foliar "yellowing" should be maximum, and if this characteristic exhibited a unique signature, then it would be possible to make a species separation.

Using the May data set training sites within each species block were selected and histograms and statistical output for the pixel values were run. Examination of the mean spectral signatures revealed that there were differences between each of the three species. The greatest differences occurred in band 7 between Scots pine and both red and white pine. Therefore, it appears that Scots pine can best be differentiated in the infrared portion of the spectrum. Examination of the output table of separation of categories showed that Scots pine may be more easily separated from white pine.

The signatures developed were input into the CLASS program and a classification run. The output classification map was compared to the previously developed cover maps. All of the areas were typed accurately using the spectral signatures developed and classified by this program. Next the program was run to include areas of the forest outside of the test area. The results of this extended test were less successful. Several areas were classified as Scots pine where none existed and several areas of red pine were classified as Scots pine.

Conclusions

Computer analysis of Landsat digital can be used to distinguish between the three conifer species tested provided that relatively large areas of pure stands are located on uniform sites. Variation in edaphic factors, which when not accounted for, lead to misclassification. Any attempts at species differentiation must consider adequate phenological knowledge of the species involved and supplementary data to compensate for edaphic and other site differences. If this combination of Landsat imagery and ancillary data could be developed, the data suggest that limited species differentiation may be possible.

Investigative Personnel

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WATER QUALITY MONITORING

Background and Objectives

In early 1979, the Vermont Department of Water Resources received a grant from the Environmental Protection Agency to attempt water quality mapping and classification from Landsat data. The actual computer processing was performed by EPA in Las Vegas, Nevada. Ground truth information was provided by the Department of Water Resources from its own water sampling stations and from 50 volunteer lay monitors located around the state. The water quality parameters sampled were chlorophyl-A, total phosphorous and secchi-disk readings.

Initial results from the project appears encouraging, but the logistics involved in transferring information from Vermont to Nevada made follow up work impractical. We were contacted by the Department of Water Resources to determine if the work could be performed locally and more timely.

Methodology

A July 21, 1979 (#21641-14540) Landsat scene was utilized to classify a portion of Lake Champlain, using Vermont's ORSER package. A portion of the false color composite from this scene covering Lake Champlain is shown in Figure 16. Water quality differences are evident from visual analysis between the southern and northern parts of Lake Champlain. By applying a parallelepiped classifier to the data, it was possible to eliminate the land and map only the water quality classes. Classified results were correlated with water parameter measurements provided by the Department of Water Resources. The results from this demonstration more than satisfied the needs of the Department of Water Resources. This map proved to be easier to interpret than the output product provided by the EPA.

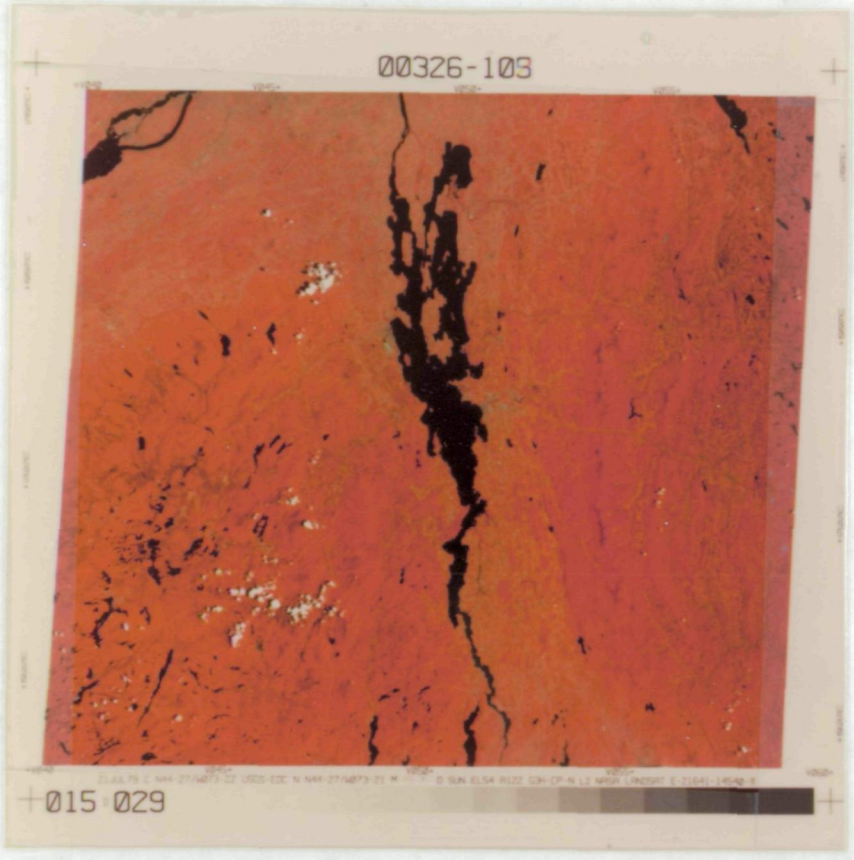

Figure 16. False color composite of the July 21, 1979 Landsat scene. Lake Champlain flows north through the center of the image.

Conclusion

As a result of this exploratory work, the Remote Sensing Applications Program and the Department of Water Resources have submitted a grant proposal to EPA to refine techniques and to continue monitoring the state's water bodies using Landsat data. If approved, the monitoring program will run for three years. Under the provisions of the proposal, the Remote Sensing Applications Program will perform the image processing. The Department of Water Resources will provide the ground truth measurements.

Investigative Personnel

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James W. Morse II, Agency of Environmental Conservation, Department of Water Resources, Lakes and Ponds Program, Aquatic Biologist, Montpelier, VT.

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

WATER USE CONFLICT STUDY

Background and Objectives

With growing demands being placed on Vermont's lakes and waterways by recreational boaters, concern has been expressed that might possibly result in further regulation of this sport. In 1980, the Recreation Management Program of the School of Natural Resources undertook a research project to analyze boating activity. Principal objectives of this project were the quantification of this recreational activity and an evaluation of the recreational experience, as perceived by the boating population. Since this project involved the acquisition and use of aerial photography and the application of photogrammetric techniques, the staff of the Remote Sensing Applications Program was asked to participate in a consulting capacity.

Methodology

The study area for this project included Shelburne and Malletts Bays on Lake Champlain and the Waterbury Reservior. Black and white panchromatic photography at a scale of 1:12,000 was flown over each of the three areas at three separate times on each of three days during the active boating season. This resulted in nine data sets. Using these data sets, boat location, type of boat, length, speed and direction of travel were measured and plotted on 1:5,000 orthophoto maps. These data, along with survey questionnaire data provided by boaters on the days of the flights, are currently undergoing analysis.

We have been able to assist this project in its initial planning phase by information on suitable photo scale, film/filter combinations, base map generation and the transfer of boat locations to the base map.

Throughout the project, staff members have continued to work with the technical staff of the study and have provided assistance and training as necessary.

Conclusions

While the analysis of data collected from this past summer is not yet completed, definite conclusions are expected. Because of the service provided by the Remote Sensing Applications Program the photogrammetric portions of this research study have gone smoothly. Maintenance of trained staff and modern facilities will enable the Remote Sensing Applications program, to continue to provide consulting services to research scientists. This will assure the proper and efficient use of remotely sensed data, which in turn will encourage greater use of this valuable information source.

Investigative Personnel

John J. Lindsay, University of Vermont, School of Natural Resources, Recreation Management Program, Associate Professor, Burlington, VT.

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Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

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WATER BODY INVENTORY

Background and Objectives

In 1980 the School of Natural Resources began a study to identify potential aquaculture sites in the State of Vermont. Data for a number of variables had to be assembled and analyzed in order to define these sites. The most important parameter for the development of an aquaculture site is water and the most desirable locations are existing bodies of water or low areas that flood and that could be converted to impoundments. Unfortunately, adequate maps indicating the location of all bodies of water in Vermont are not available. Facing what appeared to be a major obstacle, members of the project approached the staff of the Remote Sensing Applications Program to discuss the possible use of available high altitude photography. After evaluating their mapping and time requirements, we decided to utilize Landsat data to provide part of the needed information.

Methodology

The May 1, 1977 Landsat pass resulted in two cloud free scenes covering all of the state except the Champlain Islands. At this time of the year, many of the low lying areas in the state were flooded due to the annual spring runoff. These two adjacent scenes (#2830-14362 and #2830-14365) were ideal for the identification of all bodies of water in the state. A band 7 level slice of the Landsat data was used to identify and locate ponds, small lakes and flooded areas. These data were input into the ORSER "CLASS" program and a line printer map at a scale of approximately 1:24,000 was produced and delivered to the study personnel. All water body locations identified from the Landsat classification were transferred to suitable base maps for further analysis.

Conclusions

By assisting in this project, the Remote Sensing Applications Program was able to demonstrate some unique capabilities of Landsat. The desired information took only a few hours to generate, whereas identification by conventional photointerpretation techniques would have required several weeks. Of particular importance was the timeliness of the Landsat data relative to water levels. No aerial photography was available that portrayed the situation at this critical season.

Investigative Personnel

Gary S. Smith, University of Vermont, School of Natural Resources, Remote Sensing Applications Program, Program Coordinator, Burlington, VT.

UVM/SCHOOL OF NATURAL RESOURCES
REMOTE SENSING APPLICATIONS PROGRAM

YEAR	TITLE/DESCRIPTION	DATA SOURCE	COOPERATING AGENCIES	COOPERATIVE SUPPORT	COMMERCIAL SPIN-OFF	EDUCATIONAL ACTIVITIES	AGENCY CONTACTS
1978-1980	General Education and Technology Transfer	Landsat CCT and imagery, all types of aircraft and manned spacecraft photography	NASA/ERRSAC	NASA/ERRSAC	None	Training Sessions State Agency personnel (computer processing Landsat) Briefings State Agency personnel (3 occasions) Workshops Vt. Dept. Forests & Parks personnel (4 occasions) Vt. Dept. Fish & Game personnel (1 occasion) Presentations Vt. House & Senate Appropriations and Natural Resource Committees Agency of Environmental Conservation staff Burlington Lions Club	VT. DEPT. OF FORESTS AND PARKS VT. DEPT. OF FISH AND GAME STATE OFFICE/SCS UVM/COLLEGE OF AGRICULTURE VT. STATE PLANNING OFFICE
1978-1980	Systems Development for Data Handling and Analysis	Landsat CCT, high, medium and low altitude aerial photography	UVM/COMPUTING CENTER PENN STATE UNIV. NASA/ERRSAC	UVM/COMPUTING CENTER	None	None	None

UVM/SCHOOL OF NATURAL RESOURCES
REMOTE SENSING APPLICATION PROGRAM
(continued)

YEAR	TITLE/DESCRIPTION	DATA SOURCE	COOPERATING AGENCIES	COOPERATIVE SUPPORT	COMMERCIAL SPIN-OFF	EDUCATIONAL ACTIVITIES	AGENCY CONTACTS
1978-1980	Vermont Land Cover Classification	Landsat CCT, high altitude CIR aerial photography	ERRSAC VT. DEPT. FORESTS AND PARKS VT. DEPT. WATER RESOURCES	VT. DEPT. FORESTS AND PARKS/MAN-YEAR	Agency of Environmental Conservation acquired statewide coverage of high altitude CIR	Presentations (2) Briefings (6)	VT. FISH AND GAME DEPT. ADIRONDACK PARK COMMISSION
1978-1980	Land Use Change Demonstration	Landsat CCT, high altitude CIR aerial photography, medium altitude B & W aerial photography	CHARLOTTE PLANNING COMMISSION	NONE	None	Briefings (2) M.S. Graduate (1)	CHITTENDEN COUNTY REGIONAL PLANNING COMMISSION
1979	Land Cover/Use Classification for Planning	High altitude CIR aerial photography, medium altitude B & W aerial photography	CENTRAL VERMONT REGIONAL PLANNING COMMISSION	CVRPC - $500 funding	Planning consultant used data base	Undergraduate (1) Briefings (2)	TOWN MANAGERS OF FAYSTON, WAITSFIELD, AND WARREN
1979-1980	Vermont Remote Sensing Data Inventory	All known aerial photography	UVM/DEPT. OF GEOGRAPHY	NONE	None	M.S. Graduate (1) Undergraduate (1)	NONE
1979-1980	Land Cover/Use Change for Watershed Monitoring	Landsat CCT, high altitude CIR aerial photography, medium altitude B & W aerial photography	UVM/WATER RESOURCES RESEARCH CENTER SOIL CONSERVATION SERVICE	NONE	Expenditures for aerial photography and orthophoto maps	Briefings (4) M.S. Graduate (2)	CHITTENDEN COUNTY SCS CRREL-CORPS OF ENGINEERS

UVM/SCHOOL OF NATURAL RESOURCES
REMOTE SENSING APPLICATIONS PROGRAM
(continued)

YEAR	TITLE/DESCRIPTION	DATA SOURCE	COOPERATING AGENCIES	COOPERATIVE SUPPORT	COMMERCIAL SPIN-OFF	EDUCATIONAL ACTIVITIES	AGENCY CONTACTS
1979-1980	Forest Insect Defoliation Detection	Landsat CCT, high altitude aerial photography, medium altitude B & W aerial photography	VT. DEPT. FORESTS AND PARKS	VT. DEPT. FORESTS AND PARKS	None	Undergraduate (2)	NONE
1979-1980	Lake and Pond Watershed Cover Classification	Landsat CCT, high altitude CIR aerial photography	VT. DEPT. WATER RESOURCES	VT. DEPT. WATER RESOURCES. 2 MAN-YEAR.	Contract photo and scanner flights	Briefings (2) M.S. Graduate (1)	NONE
1980	River Watershed Cover Inventory	Landsat CCT, high altitude CIR aerial photography	SOIL CONSERVATION SERIVCE - STATE OFFICE	MAPS, SUPPLIES FROM SCS	None	Briefings (3) M.S. Graduate (1)	NONE
1980	Coniferous Species Differentiation	Landsat CCT, high altitude CIR aerial photography, medium altitude B & W photography	UVM/FORESTRY DEPT.	TRAVEL FUNDS FOR GRADUATE STUDENT	None	M.S. Graduate (1)	VT. DEPT. OF FORESTS AND PARKS
1980	Water Quality Monitoring	Landsat CCT	VT. WATER RESOURCES DEPARTMENT ERRSAC	VT. WATER RESOURCES DEPARTMENT. 2 MAN-YEAR.	Commerical aerial photography and aircraft scanner flights	Briefings (3)	ENVIRONMENTAL PROTECTION AGENCY
1980	Water Use Conflict Study	Low altitude B & W aerial photography, Ortho photo maps	UVM/RECREATION MANAGEMENT PROGRAM	NONE	None	Undergraduate (3)	NONE
1980	Water Body Inventory	Landsat CCT, high altitude CIR aerial photography	UVM/WILDLIFE BIOLOGY PROGRAM	NONE	None	M.S. Graduate (1)	VT. FISH AND GAME DEPT. SOIL CONSERVATION SERVICE

REMOTE SENSING COURSES AND ENROLLMENTS
UNIVERSITY OF VERMONT

Fall 1978 - Spring 1980

Semester and Year	Department and Number	Course Title	Enrollment		
			Undergrad	Graduate	Total
Fall 1978	Forestry 142[1]	Forest Photogrammetry	13	2	15
	Geography 161[2]	Remote Sensing of Environment	8	0	8
Spring 1979	Geography 261[3]	Remote Sensing and Environmental Problems	3	2	5
Fall 1979	Forestry 142	Forest Photogrammetry	21	1	22
	Forestry 285	Special Topics in Remote Sensing	0	2	2
	Geography 161	Remote Sensing of Environment	16	0	16
Spring 1980	Civil Engineering 210[4]	Photo Interpretation	20	1	21
	Forestry 285	Special Topics in Remote Sensing	0	5	5
	Geography 261	Remote Sensing and Environmental Problems	2	0	2

[1]Offered continuously since 1968

[2]First offered 1972

[3]First offered 1973

[4]First offered 1971